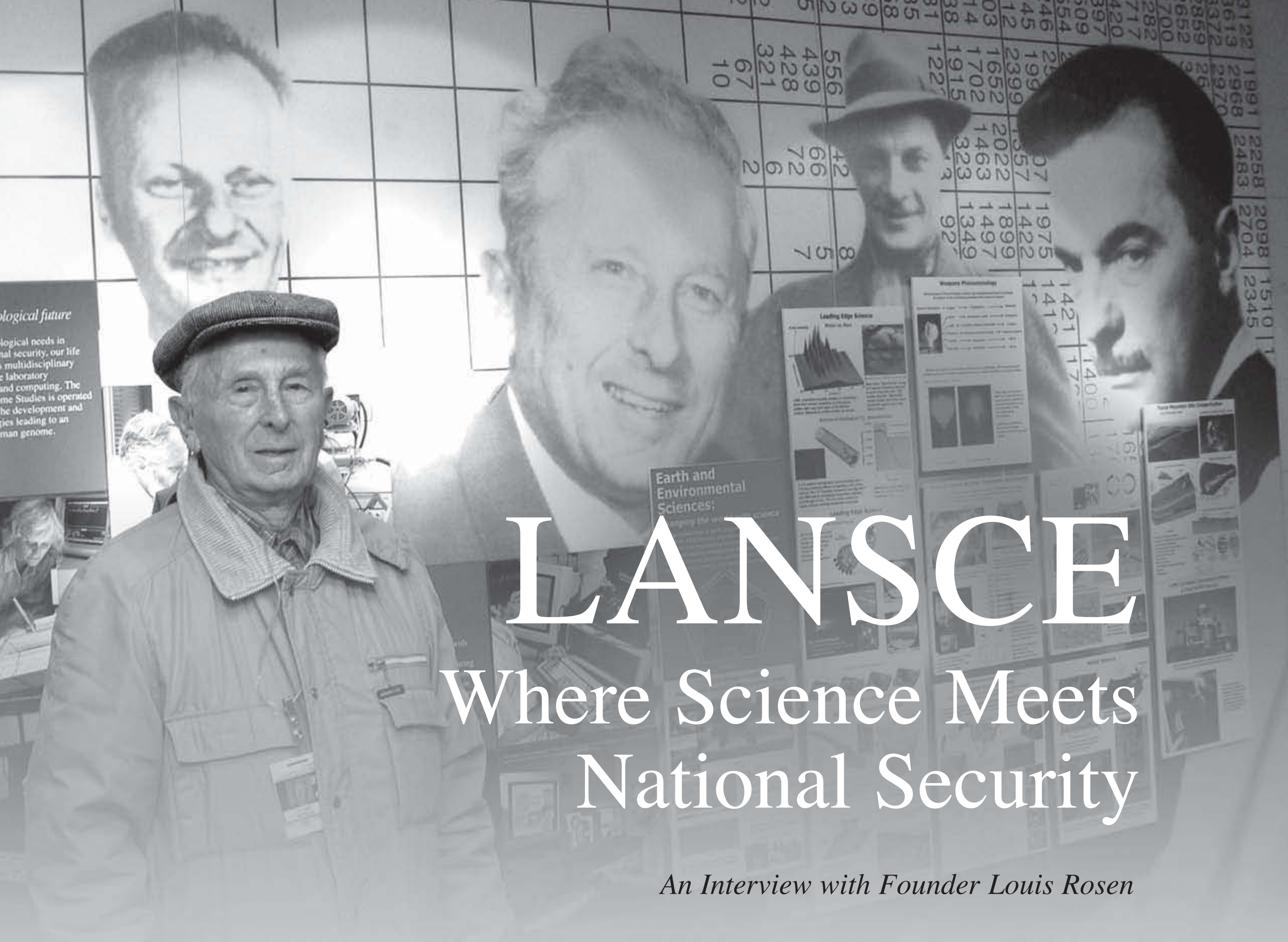


LANSCE

Where Science Meets National Security

An Interview with Founder Louis Rosen

Louis Rosen is standing near his friends; on the mural, from left to right, are Hans Bethe, Louis himself, Stan Ulam, and Nick Metropolis.

"When I testified before the Joint Congressional Commitee on Atomic Energy to justify the 50 some million dollars we wanted for LAMPF/LANSCE, I still remember saying, 'Los Alamos is emerging as a national security laboratory not only a national defense laboratory, but still our main focus has to do with nuclear energy. Whether nuclear energy is used for bombs, for generating electricity, or for any number of other purposes, the basic ingredient in the production of nuclear energy is neutrons. So one really needs to have a capability to maintain expertise and growing knowledge in neutron nuclear science and neutron technology. One thing this facility can do, as well as the basic research . . . , is provide the most-intense neutron source in the world for maintaining Laboratory expertise in nuclear physics and for training students and staff in this new field.' I then asked the question, 'How can you have a nuclear energy enterprise without strong support from nuclear science and from neutron science and neutron technology?' Somewhat to my surprise, they understood this. They believed what I was telling them. They knew I wouldn't dare try to mislead them even if I wanted to, and of course I didn't want to."

During the Manhattan Project, Louis Rosen learned from and worked side by side with the great scientists of the 20th century: Hans Bethe, Edward Teller, Stan Ulam, Nick Metropolis, John von Neumann and others. Louis' measurements turned out to be instrumental at Trinity, the first nuclear explosion on the planet. And later, at the George shot, Louis made the measurements that proved Teller's concept for a thermonuclear bomb would work. Steeped in the culture of those heroic times, Louis conceived of LANSCE as an interdisciplinary facility that would keep Los Alamos as the world leader in nuclear technology. It would be a place for fundamental science, ranging from nuclear medicine to astrophysics, and for innovation in technologies critical to national security. In the following interview with *Los Alamos Science*, Louis recounts how he made that vision a reality and how relevant it is to the challenges of today.

Los Alamos Science: Louis, you have had such a strong influence at the Laboratory and at LANSCE. It would be interesting to know where you grew up and how you became interested in physics.

Louis Rosen: I was born in New York City but I grew up in the Catskill Mountains. That move turned out to be very important because during the summers I was able to earn enough money to go to college by selling newspapers at the local hotels. I probably couldn't have worked in the City to earn the money. It was in the 30s, during the Great Depression, and it was very hard to find a job. I worked 12 or 14 hours a day selling newspapers and ice cream to vacationers, as did my brother, who went on to become executive director of the Civil Service Commission and a professor and author. Over the summer, each of us earned about $400, which was just enough to attend the University of Alabama at that time, including tuition, room, and board—everything.

I had actually become interested in science in high school, thanks to a very good high school science teacher, who was also the school coach. He was very adept at making students understand the role of science in society, even way back then.

When I went to college, I started out in premed, but to be in premed you had to take a course in premed physics. In that course, I realized that physics was really what I wanted to do, mainly, because it wouldn't take as much memory work as chemistry, biology, and all these medical courses. More important, you could figure things out from first principles. That was much more to my liking than to work cookbook style, no matter how important medical work is.

Louis Rosen at LANSCE, 2006

I changed to being a physics major and got my bachelor's of science degree, and by the time the war had started, I was teaching at the University of Alabama while working on my master's degree. After that I went to Penn State in the Ph.D. program.

Los Alamos Science: Were you already interested in nuclear physics?

Louis Rosen: At that time, my work was in classical physics. My thesis was in using x-rays to study the effects of high hydrostatic pressures on materials. In those days, which tells you something about how old I am, there were no courses in nuclear physics even in some major universities like Penn State, which was (and still is) one of the largest universities. So, when I came to Los Alamos during the Manhattan Project, I had never had a nuclear physics course. Many of us were in the same boat and that was a godsend. In the late 1930s, Hans Bethe wrote three articles, two of them with coauthors Robert Bacher and Milton Livingston. Those became the nuclear physics bible and many of us learned nuclear physics just by studying that bible. However, when I first came to Los Alamos, I did not work in nuclear physics.

Los Alamos Science: How did you get invited to join the Manhattan Project?

Louis Rosen: In early 1944, I was a graduate student at Penn State. One day, there appeared on the campus an emissary from President Roosevelt's Office of Scientific Personnel. He was recruiting for the Manhattan Project, but we didn't know that at the time. His name was Dr. Tritten. I have a very bad memory, but some things just can't be forgotten. He was a well-known scientist. After he reviewed the credentials and records of all the advanced graduate students, I was called to the dean's office. Here was this prominent scientist introducing himself and telling me, "I want you to join a project that can bring an end to the war." That was a very powerful statement. People were dying by the hundreds of thousands. Along with many others, I was trying to get into the Navy, but I was two pounds underweight. So when he said that he wanted me to join such a project, I immediately said okay. He wouldn't tell me where it was, what it was about, what I would be doing, or who I would be working for—just to come to 109 East Palace Avenue in Santa Fe, NM, for further instructions.

I was married by that time to my now sainted wife Mary, and we had a two-month old baby. They didn't have a house for us at the Project yet, so we got into my1936 Ford and went to Tennessee, where Mary's father met us. He collected Mary and the baby and took them both to her family home in Tuscaloosa. Mary arrived in Los Alamos two months later. I, instead, went directly on to 109 East Palace Avenue in Santa Fe, NM. When I got to the Hill, they told me that they wanted me to join a group. I wasn't given a choice. They said this is the group you will join, and it was to work on implosion.

Los Alamos Science: Was that about the time it was discovered that the gun device wouldn't work?

Louis Rosen: Yes. It was early 1944, and by that time it was clear that there was a big, big problem here at the Project. When the Project started up, Oppenheimer thought all he would need to make a bomb were a couple of hundred scientists. The idea was that you would eventually collect enough fissionable material—uranium-235 at first and later plutonium-239—to make two nearly critical masses. Then, you'd just use explosives to fire one into the other, you'd get supercriticality, and you would have your bomb. The questions were, "What would be the yield of this device?" and "What materials must one use?" That's why Oppenheimer thought this could be accomplished by, at the most, two hundred highly qualified scientists. But when Emilio Segrè, who had been a student of Fermi in Italy, came to Los Alamos, his first job was to study plutonium. We had only microgram quantities at that time, and the first thing Segrè found out was that plutonium had some isotopes that fissioned spontaneously, producing neutrons to such an extent that a gun device could not be used to assemble two almost critical masses. If made with plutonium, it would predetonate, and that was the big problem they now had to solve.

The Trinity Tower

The bomb was in place on the tower. Everything was in readiness, awaiting the results of a pretest at Los Alamos involving a full-scale implosion but with a surrogate for the plutonium. The results were a cliffhanger.

Early in 1944, Oppenheimer began bringing many, many more scientific and technical engineering people to Los Alamos. A way had to be found to assemble a subcritical mass of plutonium fast enough and uniformly enough to create a supercritical mass for a long enough time to provide a reasonable energy release. It was soon realized that the only possible method was explosive-driven compression—in other words, implosion. So, many groups were set up. My group leader was Ed McMillan, and my division leader was Bob Bacher. Those were pretty high-class people. McMillan achieved Nobel Laureate status, and Bacher became provost at CalTech. I had a lot of fun just being able to talk to people like that. I had never had that opportunity before.

My group was among those working on how to use high explosives to assemble a mass of metal under the conditions that we hoped, when the metal was replaced by plutonium, would ensure a proper energy release. The first metal we worked on was aluminum. Whenever we set off an implosion experiment, shards of red hot metal would fly into the canyons, setting fire to dry wood and leaves. We would have to stop everything, and everybody would fight fires. This was almost a daily occurrence. At one point, the shops ran out of aluminum, and without telling us, they substituted magnesium. It has about the same density, and you can't really see the difference, but magnesium is what you use for firebombs. Needless to say, we had quite a problem that day.

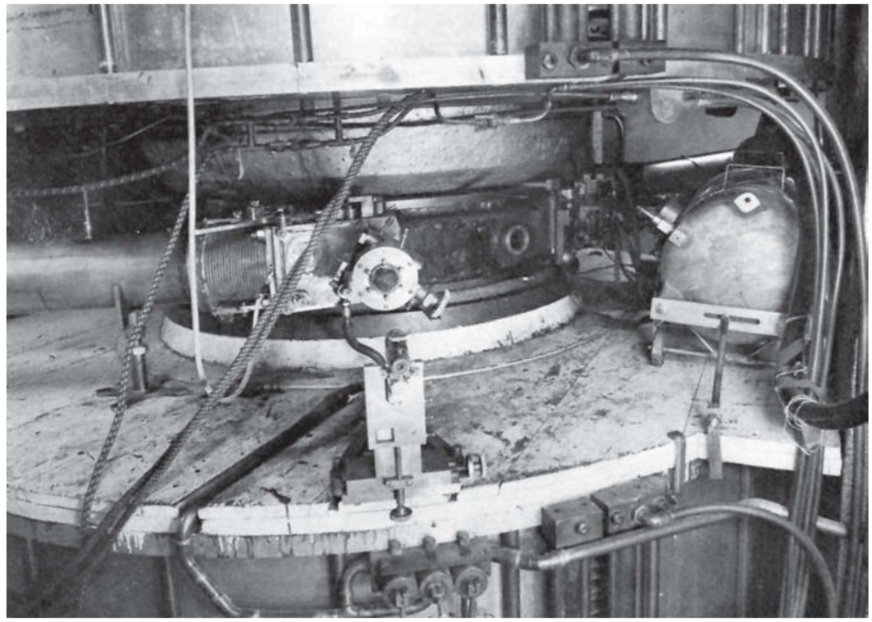
The magnetic method of studying implosions, which yield the collapse time and final density of the material being imploded, relied on electromagnetic signals produced by a conducting material moving in a magnetic field. These signals had to propagate through the explosive residue, which is ionizing. There was a question of whether the rise time of the signal would be distorted by the detonating explosive. Sometimes, when there were no new explosive designs to test, I took it upon myself to measure that effect. It was not a requirement; I was just interested in the results. I documented them in my reports, but I never knew that anyone noticed them, not until Hans Bethe kindly informed me of the following episode at the Trinity test.

Uncertainties about implosion continued to the very end, and the final hours before the test were no exception. The bomb was in place on the tower. Everything was in readiness, awaiting the results of a pretest at Los Alamos involving a full-scale implosion but with a surrogate for the plutonium. The results were a cliff-hanger. The electromagnetic signal looked different than expected, and everyone waited for Bethe to interpret them. Bethe looked at the curve and calculated the results from first principles, but he anchored his results in the experiments that, unbeknownst to me, he had seen written up in my reports. He concluded that all was well and the test went ahead.

The journey to Trinity was bumpy and very stressful, to the very last moment. But the experiment achieved the first violent release of nuclear energy on this planet.

Los Alamos Science: How do you view the impact of the Trinity test and your involvement in it?

Louis Rosen: The success of Trinity heralded the termination of World War II, with the saving of many lives on both sides and in occupied China. We now know that the emergence of nuclear energy and its utilization as a weapon, as well as for all manner of peaceful pursuits, was inevitable dictated by the laws of nature. That the development of nuclear weaponry was first mastered by a democracy, rather than by a Hitler or a Stalin or a Saddam Hussein, must certainly stand as one of the most fortuitous occurrences in all of history. In addition, Trinity opened the door to environmentally friendly and affordable energy at a time when we must plan for greatly diminished use of fossil fuels. This will hopefully help to contain international instability. That, to me, is the promise of Trinity and the validation of my modest contribution to the effort.



The Harvard Cyclotron

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Los Alamos Science: Did you choose to stay at Los Alamos after the Manhattan Project?

Louis Rosen: Yes. Right after the war, people had a choice of what to do. I decided, after reading Bethe's bible, that nuclear energy was something the world would definitely need. Even back in high school in the 30s, we were being told that the world oil supplies were going to disappear eventually; they estimated about 50 years or so. Now, in 2005, it is starting to happen and so is global warming. What does one do? It seemed to me that nuclear energy was an obvious choice. I decided to become a nuclear physicist and joined the cyclotron group. During the Manhattan Project, Bob Wilson had come from Harvard to run the cyclotron. But after the war, most of the great people left, and we had to start rebuilding these groups. The cyclotron had been liberated from Harvard for the war effort, but they didn't want it back, and we didn't want to give it back, so we bought it from them.

It was a very temperamental machine, but Stan Hall—he's still here—was a sergeant during the war and an expert on the cyclotron, and he could get a beam out when nobody else could. One day, Stan was working at the control desk, and he was having a beer, which was okay at that time. In comes a general on inspection, his eye catches this beer-drinking sergeant, and he says to him, "Soldier, is that necessary?" and Stan replies, "Sir, it won't run without it." The general graciously retreated.

After the war, I worked with the cyclotron, but it was still very temperamental. The first problem I tackled was to get certain fundamental scattering data between like nuclei. Almost nothing was known about the interactions of light nuclei with themselves and with each other. But you needed to take data at many angles, and it was so hard to get the machine to run long enough even for one angle. So I decided to develop a technology that would get data at all angles simultaneously. It became known as the nuclear multiplate camera. That was the beginning of the Laboratory's efforts to develop nuclear-detector technology, which turned out, as I will explain in a moment, to be a blessing in disguise. With this camera, we could get angular distributions for scattering reactions for deuterons with any target nucleus within a 30-minute run. It was marvelous, and I set up the first nuclear microscopy group. We hired young ladies, most of whom had a college degree and knew mathematics, and they became superb microscopists. It was hard work, and we would permit them to work only 4 hours a day. But that was all they wanted to work, so it was perfect.

Los Alamos Science: What were those nuclear plates?

Louis Rosen: The nuclear plates were glass plates covered with a high-density silver bromide emulsion—like you have in ordinary film, but with a much higher density of silver. The emulsions were very thick, hundreds of microns thick, and they would record the tracks of the charged particles. From those tracks we could figure out the direction, energy, and charge of each particle going through. We developed that technique as did others in England and elsewhere.

I used that technique to measure nuclear cross sections (both neutron and charged-particle) for some years and published many papers. Everything one did in nuclear physics was brand new, so there was no problem publishing in refereed journals. The interesting thing is that, although originally I thought my work on basic research was without any practical importance, I was wrong. It soon appeared that the thermonuclear program needed neutron energy spectra and cross sections for a host of materials. The electronics of that period could not give definitive energies of neutral particles that entered proportional or fission counters. So I decided to develop the nuclear-emulsion technique for neutron spectroscopy. We measured neutron spectra for essentially all the important materials related to fusion weapons. We had a Cockroft-Walton accelerator, which provided 14-MeV neutrons from deuterium-tritium fusion reactions, and that was our chief neutron source.

Los Alamos Science: So, your measurements became very important to the development of the hydrogen bomb.

Louis Rosen: Yes. At one point the theorists needed to know how 10-MeV neutrons would interact with materials because, if you have 14-MeV neutrons from fusion, they will degrade and you'll have neutrons at 10, 9, and 8 MeV. This presented a problem. We did not have any source of neutrons except at energies of a few million–electron volts and then 14 MeV. But, Professor Gregory Breit was here, and he said, "Look, if you will get me proton data at 10 MeV, I will calculate what the neutrons would do at that energy. But we didn't have 10-MeV protons. The cyclotron would give 10-MeV deuterons, but it wouldn't accelerate anything else at that time. So Norris Bradbury, our Lab Director, called E. O. Lawrence, and Bradbury said, "Look, we need to use your cyclotron for some experiments," and Lawrence said, "Absolutely." So they interrupted their programs, and we, with our multiplate camera, microscopes, and plate readers (those were people!), descended upon Berkeley. In order to extract the beam from the cyclotron, they had to cut a hole in one of the magnet pole pieces, which are made of very thick iron. At first, they were really upset to cut a hole in their beautiful cyclotron and wondered what that would do to the magnetic field. After we established that it wouldn't do anything to the magnetic field, they got the welders and cut a hole. We put in our beam pipe, got the beam out, and did experiments with 10-MeV protons on all the materials requested by the theorists. Then Gregory Breit calculated what 10-MeV neutrons would have done, and everything was okay. The Berkeley graduate student who ran the cyclotron was permitted to use our camera to do an experiment for his thesis. He later made his career at Los Alamos. His name was Tom Putnam.

But that's not the end of the story.

Finally, it was decided that the Teller Super wouldn't work. Teller wouldn't believe the calculations at first, but then Fermi did his own calculations and said, "Edward, it just won't work." It looked like there was no way to ignite the thermonuclear fuel. At that point, Stan Ulam suggested, "Why don't we use a fission bomb to heat up and ignite the thermonuclear fuel?" When Teller heard this, he immediately realized, "That's the answer, but how do you arrange a fission bomb so that it'll do what you want it to do?" How do you arrange things so that the energy from that bomb will be focused in the right way to make high-density thermonuclear fuel with a temperature of millions of degrees? Teller came up with the idea to use the radiation from the fission bomb. Everybody thought, "Wow, this may be the answer." But how do you know it's going to work?

It was decided to have a test. At that time, a large set of tests was being planned at Eniwetok—the Greenhouse series. The electronics were still not good enough to measure neutron spectra. However, to know whether the thermonuclear fuel ignited, you had to measure the number of high-energy neutrons coming out and their energy distribution. That measurement was especially important because the energy released would be too small to be distinguished from that released from the fission bomb. So, how does one determine whether Teller's idea really worked? Well, you had to measure the 14-MeV fusion neutrons. It was the only way. A large number of groups were set up to do electronic measurements detection. They didn't want to measure the energy; they just wanted to be sure that 14-MeV neutrons were produced. There was a big group from the National Naval Research Laboratory, a group from the University of California, and a number of groups from this laboratory, all using electronic equipment. I made a proposal that we use nuclear emulsions. Everybody thought that had to be the craziest idea ever. Nuclear emulsions could only withstand a few hundred millirem of radiation before they would turn black. And how were the glass plates going to survive a several-hundred-kiloton bomb? Well, Bradbury called a big meeting with all the division leaders, and I was invited to the meeting to present the proposal for this experiment. People's eyes just glazed over. Only one person said, "I think we ought to try this other approach." That person was Bradbury,


The George Shot

and that was enough. One vote canceled all the others.

So, we started getting ready for this experiment, and we went down to Eniwetok to supervise the installation and alignment of these enormous multiton concrete collimators. It was a huge experiment. My first thesis student at Los Alamos, John Allred, had joined my group, and we were working together with a number of other people to mount this experiment. The explosion was set off one evening, as soon as it got dark, so you could take pictures. When the test went off, it was immediately known that all the electronic experiments had failed. Not one of them provided a clue as to whether 14-MeV neutrons were produced. But because of the radiation fields, we couldn't collect our detectors for 24 hours.

The next evening, we went in to collect our film. We had a six-by-six truck and we had a lead cask to protect the film, but there was no protection for the people. The health division regulations allowed us to accumulate a few hundred millirem, but still we had to get in and out very fast to stay within that dose. John, I, and a radiation monitor went in, and as we were driving through this field of radiation with the detectors ticking continuously, the monitor said to John, who was driving, "What happens if this breaks down?" John replied, "I don't know, you just try and catch me." We finally arrived at the 400-meter collimator, quickly unbuttoned the shield, retrieved the plates, and put them in the lead cask. They were now safe. Off we went back to the lab.

We processed them that night. The next morning, just at daybreak, there was a pounding on the lab door. It was Edward Teller. Many of the experimentalists and theoreticians knew that the results of this experiment were crucial and that, if they were to have any data at all, the data would come from these emulsion plates. So, they stayed up all night playing poker and that's why Edward was up this early. He came in and said, "Louis, "did we get 14-MeV neutrons?" I said, "Edward, the plates are processed, but they are being washed, and then they have to dry." "Oh no, no. You can sacrifice one. Just take one out and see if it has the 14-MeV neutron signature." He was right; we could sacrifice one. So, I took it out, put it under the microscope, and this was one of the most exciting moments of my career. Here were these beautiful proton recoils, which had just the right energy to be from14-MeV neutrons. We used absorbers to take out the proton recoils from fission neutrons. I had previously calibrated the microscope so I could determine from the number of proton tracks in a given field how many 14-MeV neutrons would have been generated. I looked at the plate not more than 20 seconds, and I said, “Edward, it’s okay. You’ve got 14-MeV neutrons, and many of them." “How many?” Fortunately, I could tell him.

Then, much to my surprise, Edward, who usually walked with difficulty because of his artificial leg, went dashing out the door. I could not imagine where in the world he was going. Our lab was right next to the airstrip, and I watched Edward head for the airstrip and go out to the middle. A plane was taking off, and he waved for the plane to stop. It stopped, the door opened, and he handed something to whoever was in the plane. The door closed, Edward got out of the way, and the plane continued to take off. It was 15 years before I knew the end of the story. Edward and I had traveled to Albuquerque from Washington, and I offered him a ride to Los Alamos. It was hard for him to get into the little planes that flew to Los Alamos, so he was grateful for the ride. On the way home, it occurred to me to ask him, “What happened on that day that you came in and wanted to know whether you had 14-MeV neutrons?” Edward replied in his inimitable style, “All right, I’ll tell you.” He began by telling me that some months earlier he had been invited to give a colloquium for the students at the University of Texas, and when he finished his talk, a pretty young lady got up and said, “Professor Teller, did you ever commit a security breach?” Surprised by the question, he thought for a few seconds, and then he said, “Yes, once. But it was not my fault. It was the fault of Louis Rosen.” He continued with his story, telling me that he had had a bet with E. O. Lawrence, a 5-dollar bet. And although the idea was his, he bet that it wouldn’t work—that there would be no significant burning of the thermonuclear fuel. But it did work, so he had paid Lawrence the 5 dollars and had done this in an uncleared area, which meant he was giving Lawrence classified information in an uncleared area. That was a security breach, but it was my fault because I gave him the data!

Bradbury recognized that the Laboratory had to diversify if it were to remain a world-class laboratory, which, . . . was absolutely essential for the security of this country. So Bradbury lassoed the Laboratory and morphed it from a national defense laboratory into a national security laboratory. Of course, national security includes national defense, but it has many other aspects. Environmental security, food security, energy security, economic security, and now antiterrorism,

Los Alamos Science: After being so involved with the nuclear weapons program, how did you get the idea to build LANSCE, or LAMPF as it was originally called?

Louis Rosen: Well, Los Alamos started as a national defense laboratory. It first invented the fission bomb, then it invented the fusion bomb, and then it miniaturized both. What does one do for an encore? It was essential for the development of those weapons that we have very broad expertise in science and technology, not only in nuclear physics, not only in metallurgy, but in many fields. We had assembled the scientific staff to do that. And it had been a superb staff. After accomplishing your main mission as a weapons laboratory, how do you maintain the skills necessary to make sure that the weapons you stockpile remain safe, secure, and reliable? And how do you maintain the vitality of the Laboratory? And how do you maintain the skills to resume testing if necessary, in the almost certain event that there is a test ban? And how does the Laboratory position itself to contribute to national security in the broader sense?

By the middle of the 1950s, Bradbury recognized that the Laboratory had to diversify if it were to remain a world-class laboratory, which, he felt as did others at that time, was absolutely essential for the security of this country. So, Bradbury lassoed the Laboratory and morphed it from a national defense laboratory into a national security laboratory. Of course, national security includes national defense, but it has many other aspects. Environmental security, food security, energy security, economic security, and now antiterrorism, they all fall under national security. Norris set out to diversify the Laboratory, and several things were attempted—nuclear rocket propulsion, thermal neutron reactors, fast neutron reactors, high-temperature gas-cooled reactors, and fusion energy. Those programs achieved many technical successes, but for one reason or another, they did not become part of our main mission.

During the same period, nuclear physics was still classical nuclear physics. It ended at 10 MeV. The Laboratory had led the world in nuclear physics for a while, but the details of nuclear physics being explored at that time didn't have too much to do with daily life, and interest in the field was diminishing. This presented both a problem and an opportunity. Another fortuitous thing then happened. My sainted wife Mary decided that we had to get away from Los Alamos for a while. I didn't want to leave as I was pioneering and publishing the results of new experiments, but I realized she was right. So, I applied for a Guggenheim Fellowship. The time for applications had passed, but I told Bethe and Teller, and they somehow arranged to get the deadline extended. I was awarded $5000, which was a lot of money at that time, and I became one of the first people to go on a sabbatical from Los Alamos. The Laboratory paid half my salary. With that plus the $5000, we could practically live like kings. We could have gone either to Paris, or Tokyo, or Oslo, and Mary chose Paris. We got an invitation to the Center for Nuclear Research at Saclay. They knew about my pioneering work on polarization and they wanted to start a polarization program there. So, off to Paris we went. During that year, I had time to think about how to rejuvenate nuclear physics and make Los Alamos once again a world leader in that area. It seemed to me that building an accelerator with not 10, but 1000 to 10,000 times the intensity that was available anywhere in the world (for energies above the pion production energy, at least 400 MeV) would open up new physics regimes. Students, faculty, and other scientists would be attracted to Los Alamos, maybe spending part of their time working with this facility and part on weapons physics.

When I got back to Los Alamos, I wrote a memo to Jerry Kellogg. He was Physics Division leader and a former student of I. I. Rabi. And I told him why I thought this new facility would be extremely important for the vitality of the Laboratory, for the nuclear weapons program, and for the health of nuclear physics. There was talk of building a nuclear energy economy at that time, which I hope will still happen. It's more likely now than it has been for some time. But how do you build a nuclear energy economy if you don't have a basis in nuclear science to increase your understanding of nuclear phenomena and to train students in nuclear technology?

Kellogg thought I had a pretty good idea and sent the memo to Bradbury. Bradbury said, yes, he would support the proposal provided Louis Rosen would stop everything he was doing and devote all his time and effort to making this happen. Well, that was a big sacrifice for me, and it took me a little while before I decided that I was young enough to take the risk. If we failed, I could still go on to another career. It wasn't a sure thing that we were going to succeed, not at all.

Bradbury took money from the weapons program to support preparation of the proposal because he realized that this new facility was needed to maintain the health of the Laboratory as a weapons laboratory. It could do science for the sake of science, but also for the sake

(Left to right): Senator Clinton P. Anderson, Glenn Seaborg, and Louis Rosen at the Groundbreaking for LAMPF

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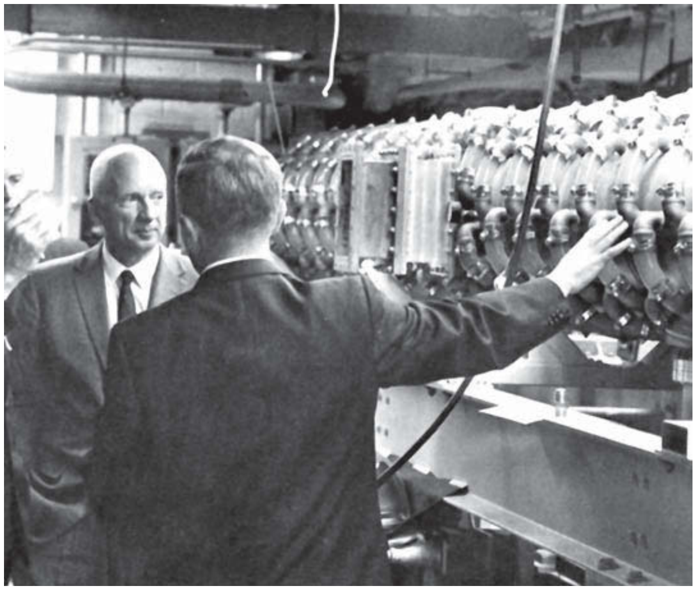
of developing technologies for the broader aspects of national security. So that's how I became an advocate for LAMPF, the Los Alamos Meson Physics Facility, which has now become LANSCE.

Los Alamos Science: How did you manage to get the support for this new facility?

Louis Rosen: Well, before trying to sell the idea to Congress, we made sure that everybody in the Laboratory, especially the weapons people, saw this facility as an important contributor to their activity, and one of the things we built purposely for that work was the Weapons Neutron Research (WNR) Facility. We also had to get the scientific community to understand why the new facility would be important for them as faculty and for their students. So, we set out on a campaign to talk at universities, and we set up a users group even before we had money for the accelerator. The nuclear physics community was worried that this facility would take money away from classical nuclear physics, so it took some doing to get the support of a very substantial fraction of that community.

Of course, the key to success was Congress. Here I was very lucky because the Atomic Energy Commission was made up of people who understood science. Glenn Seaborg was the chairman, and I knew Seaborg. He not only understood the science we were trying to address and that this would be the first multidisciplinary facility of its kind in the country, but he also understood how important it was for the maintenance of Los Alamos as a world-class laboratory to support world class stewardship of the nuclear stockpile. Seaborg also knew about some very important experiments that I had done having to do with weapons. The measurement of the 14-MeV neutrons was one, but



Director Norris Bradbury and Louis at the LAMPF Accelerator

then there were others—the neutron spectroscopy work, the neutron cross section work, and the problem that the second thermonuclear weapon ever tested yielded a much higher amount of energy than anticipated. It was almost a disaster. The questions were, "Where did this energy come from?" "Why were the theoretical estimates so wrong?" It turned out that I had done an experiment that indicated where this energy came from. Now, Seaborg knew this, and he told Congress how we had surmounted those problems.

So, when I testified before the Joint Congressional Committee on Atomic Energy to justify the 50 some million dollars we wanted for LAMPF, the Joint Committee knew me by the reputation that Seaborg had established. I was also very good friends with Senator Clinton P. Anderson, the chairman of the Joint Committee for Atomic Energy. I still remember saying to them, "Los Alamos is emerging as a national security laboratory not only a national defense laboratory, but still our main focus has to do with nuclear energy. Whether nuclear energy is used for bombs, for generating electricity, or for any number of other purposes, the basic ingredient in the production of nuclear energy is neutrons. So one really needs to have a capability to maintain expertise and growing knowledge in neutron nuclear science and neutron technology. One thing this facility can do, as well as the basic research with pions, neutrons, and neutrinos, and directly with protons, is provide the most intense neutron source in the world for maintaining Laboratory expertise in nuclear physics and for training students and staff in this new field." I then asked the question, "How can you have a nuclear energy enterprise without strong support from nuclear science and from neutron science and neutron technology?" Somewhat to my surprise, they understood this. They believed what I was telling them. They knew I wouldn't dare try to mislead them even if I wanted to, and of course I didn't want to. Although there was then, as now, a very difficult budgetary situation, they decided to go ahead with this facility, the most expensive nuclear physics facility ever proposed. They authorized and then allocated the funds to build LAMPF, which is now LANSCE.

Los Alamos Science: Didn't you make a rather audacious promise when you said that the new accelerator would produce a beam with an intensity much higher than had ever been achieved before?

Louis Rosen: Yes, the unique feature of the facility would be a beam of 800-MeV protons with an intensity at least a thousand times greater than anything on the planet. We were able to deliver on that promise because we were able to attract some of the very best people at the Laboratory. Three were in Project Sherwood (the fusion project), Darrah Nagle, Ed Knapp, and Don Hagerman; they were the creative and highly innovative people who invented the new accelerator—the side-coupled cavity—without which we couldn't have built the facility. They and their extraordinarily capable colleagues also led the design and construction effort. Standard linear accelerators—the type Louis Alvarez had invented—would only accelerate particles to a maximum energy of 200 MeV without becoming impossible from the standpoint of energy requirements. (We eventually used a 100-MeV Alvarez-type accelerator as the injector for the main accelerator in the LAMPF accelerator.) On the other hand, the beam loss in cyclotrons would be so great that it would be impossible to reach the intensity we wanted. Others who wanted to develop meson factories—the Canadians and the Swiss—realized as we did that technology was not at the stage where a circular machine could achieve such high currents. Eventually, they opted for a hundred microamperes in beam intensity. But we wanted a milliampere, so we had to pin our hopes on a linear machine. We reached that goal with the side-coupled cavity of Knapp, Nagle, Hagerman, and their colleagues, and it has had profound consequences, not only permitting us to build LAMPF on schedule and on budget, but every multihundred-million-electron-volt proton linac built today uses that design. It has made possible efficient and stable mega-voltage x-ray machines. All companies that build mega-voltage x-ray machines now use that design. It's gotten more compact, it's more reliable, and it has helped hundreds of thousands of cancer patients, millions probably, get better therapy than they otherwise could have got. So that's the way basic research works. It reaches out in ways that are unpredictable. It also stimulates technology. LAMPF was the first accelerator designed for complete control by computers. This is now standard practice.

June 10, 1972—Achieving the Design Beam Energy of 800 MeV on Louis' birthday

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Los Alamos Science: In addition to delivering very high intensity, LANSCE seems to have many innovative features that make it a very flexible machine.

Louis Rosen: We were interested making the machine as useful as possible. For example, LANSCE was the first dual-beam machine ever built. It uses both halves of the radio-frequency cycle to accelerate negative and positive ions simultaneously. That idea actually came from the Canadians. This makes possible twice as many experimental ports as you otherwise would have. But we did it for another reason. An important aspect of nuclear physics is identifying and exploring the different forces involved. One, which was very hard to understand, was what we call the spin-orbit force. This force comes from the fact that all nucleons (neutrons and protons) and most nuclei have net spin, clockwise (up) or counterclockwise (down). If the particles in a beam have all the same spin, the beam is said to be completely polarized. To study this spin orbit force required polarized nucleons, and with two beams, negative and positive, we could dedicate one to a polarized beam, which eventually had significance for the weapons program in the following sense. With the polarized beam it was possible to better parameterize the optical model for describing nucleon–nucleus interactions. By getting a better optical model one no longer had to measure nucleon–nucleus interactions for every angle and every energy and every nucleus. One could use this model to extrapolate between energies and angles, and it relieved a lot of the problems, providing data for the theorists to do their modeling of how nuclear weapons work. So, here was a purely basic research question that reflected on the practical applications of nuclear energy. Victor Weisskopf was the one who had a lot to do with the development of the optical model, and it is still used. It has better parameters now than it did when I was young. But it is still used, and it still gets its parameters from the same data.

Los Alamos Science: In addition to nuclear physics, isn't there a strong program in fundamental physics at LANSCE?

Louis Rosen: Yes, but there is also a lot going on now at LANSCE that was not considered nuclear physics 30 or 40 years ago—mainly because one didn't know how to access these questions. For example, at LANSCE they are planning for ultrahigh-precision neutron lifetime experiments and parity-violating experiments with ultracold neutrons. These do not have obvious practical applications; however, LANSCE is important as a magnet for recruiting people to the Laboratory. LANSCE brings to the Laboratory people with talent and ideas from all over the world. You cannot have world-class science if you don't interact with the world community of scientists, and LANSCE is a vehicle for promoting that interaction.

But LANSCE does one more thing that might not occur to everyone. It contributes to reducing international tensions by inviting to LANSCE scientists from nations that are not particularly our friends. Even during the Cold War we gave access to Soviet scientists, and one of the most important things I ever did was to make it possible for scientists from the People's Republic of China to come to this Laboratory, work at LAMPF, and stay much longer than the canonical 8 days that were allowed at the time. And that has an interesting history.

Sometime in the 1980s, I received an invitation from the Chinese Academy of Science to come to China with my wife under the following arrangement: If I provided three lectures, one of which had to be on energy, they would take us anywhere we wanted to go in China. When I mentioned this to Mary, it took her no time before she had an agenda of where we should go in China. I got permission from the Laboratory and Washington to go to China, and off we went. When we got to there they treated us like royalty. They told me where I would lecture, and I provided the lectures, but they also permitted me to visit any laboratory. I chose the major science laboratories. When our visit was almost at an end, a messenger from Fong Yi, the deputy premier in China at that time, told us that Fong Yi would like to talk to us in the royal palace in the Forbidden City and asked whether we would be willing to meet with him. Of course we agreed, and the next morning we were taken to the Forbidden City in a black limousine. There, at the emperor's palace, we were confronted by a huge number of stairs leading up to the palace proper. Fong Yi and his entourage had come down halfway to meet us, and it was up to us to mount the stairs. But Mary already was having trouble walking as she had had polio and I wondered how in the world we were going to get her up those stairs. But I needn't have worried. They had arranged for two very stout Chinese officers to butterfly her up the stairs while I tagged along behind. We then introduced ourselves, went up the rest of the stairs to his office, Mary with her accomplices, and had an hour-and-a-half conversation.

People don't realize the close interplay between basic research and the emergence of national security technologies. LANSCE development was responsive to the fact that technology is truly the child of science.

He took half the time to tell me about the advances China had made during the great march. The other half I talked about what I had found out about his laboratories—the good and the bad. Then he said, "Now Professor Rosen, I do not have even a high school education, but I am in charge of all the science, technology, and education in all of China. If you were in my place, what would you do to catch up with the West in science and technology?" I had not anticipated the question (although I should have suspected something like this), but after thinking for a minute or two, I said, "Well, the first thing I would do is identify, every year, some hundreds of your brightest young scientists and engineers and send them to centers of excellence, not for a week or a month, but for a year or even two years. That way they can become engaged not only with the frontiers of science and technology but also with the environment that permits science and technology to flourish. He replied, "Yes, Professor Rosen, that's a very, very good idea. Now would you accept some of them at your facility?" Now I understood the reason for our invitation and the reason for all the things that had happened before. My answer was, "Mr. Vice Premier, the rules of the government right now are that we can accept Chinese citizens at Los Alamos for only 8 days, but if you will nominate scientists whom we know by their reputation, I will do what I can to get that rule changed." About 3 months later, a letter came from his deputy for science nominating three or four renowned people. One was director of their main nuclear physics laboratory, another was a group leader of the chemistry group, and a third was an expert on radioactive nuclei. Congress had already been persuaded that LAMPF must be an open facility if world-class science and technology was to continue at the Laboratory. I'm not sure that everyone in the present Congress understands that, but the Joint Committee on Atomic Energy did.

Now the monkey was on my back. Fortunately, if you're lucky, you don't have to be smart, and I have been lucky many times. This time, it turned out that a former neighbor of mine, Herman Roser, who had been the Atomic Energy Commission presence at Los Alamos, was made head of the Division of Military Applications in the Atomic Energy Program. It was up to him to decide what the security rules were. I went to see my friend Herman Roser and told him, "Look, if we could make friends with these people, one quarter of the people on Earth, it would be worth more than any number of aircraft carriers or bombers that we could possibly build." He understood this. In a few months word came that "yes," we could invite these scientists. They were marvelous visitors and worked all hours of the day and night. I suspect that our initiative was a factor in improving our relations with China at a critical time. Without LAMPF, we couldn't have done that, and now LANSCE serves a similar purpose. So, in addition to direct and unique contributions to national security, LANSCE also fosters an environment that encourages a symbiotic relationship among national laboratories, academia, and relevant industries.

Los Alamos Science: Isn't LANSCE also important as a source of radioisotopes for medicine?

Louis Rosen: Yes, these are radioisotopes that cannot be produced by reactors. They are proton rich, whereas reactor radioisotopes are always neutron rich. Thus, we more or less double the radioisotopes available for medical diagnosis and treatment and for industrial purposes. In the original plans for the facility, I decided to include specifications for a radioisotope facility that would not interfere with anything else going on. It would be put at the end of the beam line, where the beam goes to a beam dump. That beam dump eventually became a neutrino source—even back then we used everything from the hog including the squeal. We built the radioisotope facility, and it functioned very well. Unfortunately, the accelerator is sometimes down for long periods, either for maintenance or because the budget will not support the electricity it demands. It uses 20 megawatts of power when it's running full steam. But we had the foresight to do something that has only now come to pass. We provided a space between the 100-MeV section and the 700-MeV section of the accelerator, a space where a magnet could be installed to deflect the beam to the north into what we hoped would become a radioisotope facility to produce radioisotopes year round, whether the main machine is down or not. In addition, it could also use the negative ion beam to produce radioisotopes. It's only in the last few years that funds became available to build an isotope production facility at this juncture between the phase one linear accelerator and the main accelerator. And it's marvelous for a lot of reasons—not just medical. You see, at WNR we measure neutron cross sections. That was one of the main reasons for establishing WNR in the first place, and those are still being measured because the weapons program is a black hole for neutron cross sections. It needs all it can get. Some of the needed cross sections are for short-lived radioisotopes that are made when a nuclear weapon detonates. They are so short lived that you can't make them at Oak Ridge or Brookhaven and bring them here. There's not enough time. With the new radioisotope facility, we can make the radioisotopes and quickly transport them to the WNR to make measurements. Again, that is a weapons measurement that the radioisotope facility uniquely makes possible.

Los Alamos Science: What do you see as the role of LANSCE in the future?

Louis Rosen: Today, national security, including economic security, involves characterizing, improving, and inventing materials as never before. Neutrons, including ultracold neutrons, are indispensable probes. With proper upgrades LANSCE can meet the civilian and military requirements far into the future.

People don't realize the close interplay between basic research and the emergence of national security technologies. LANSCE development was responsive to the fact that technology is truly the child of science. It's very important that those responsible for planning the future of the Laboratory understand the unique utility of LANSCE for both science and national security and how important it is for the nation that this facility be imbedded in a national security laboratory while being open to the world scientific community in its unclassified research activities. ■